establish that their whole effect in altering the energy of motion of the two bodies at any instant is divisible into two parts, that which the forces, removed to the centre of mass of the pair, and acting there on their joint mass, will have on the joint mass in absolute space, and that which is represented by the sum of the bodies' changes of actual energy reckoned in a space which has this centre of the masses for its origin. If we call the latter changes their local changes of energy, and professing ourselves entirely ignorant of motion and position in absolute space, confine our attention to describing the motions of the bodies in the specified or local space, the abstract laws of dynamics again tell us that in this local space the motion of the bodies is what arises from an equal and opposite action and reaction exerted mutually between them. Suppose this to be of the permanent kind above described (which occurs frequently in natural actions, as already mentioned), then as regards the local motion and its forces (now equal and opposite, and quite distinct from what they were abstractly), the above proposition may be predicated of them which asserts that the local energy of motion and local potential energy together have a constant sum. In our circumscribed sphere of observation the energy of motion is entirely known, or in other words, if we follow the bodies along any course from one point to another, not only all the changes and the sum of the changes of their actual energies, but also their energies at first, and therefore their energies at last, are known by a successive process of integration. We know from the permanency of the energy-gradients along the line of centres that the sum of the energy changes between the two given points is independent of the course or lapse of time in which the final point is reached. Instead, therefore, of making a new successive integration for every course, one such integration for all expresses the total change of energy between the points, and as this is possible for all points or configurations which the bodies can reach from their first configuration, if a scale of such energy changes reckoned from some starting one is made out for all the different distances from each other at which the bodies can be, the scale value will be nothing at the starting distance, and will have determined values at all other distances. We would use the scale by saying that the actual energy at any distance only differs from the scale value by the starting-energy to be super-added; or the excess of the actual energy above the scale value is everywhere constant, and everywhere equal to the actual energy at the initial point. This concise description of the motion, as far as the actual energy at any moment is concerned, accords with the mathematical usage of collecting variable quantities thus simply related to each other and to constant quantities on one side, and constant quantities on the other side of an equality; but a further simplification of its expression is effected if those scale values which mean increase of energy from the starting-point are called "negative," and those denoting loss or decrease of actual energy are called "positive"; for having constructed a new scale on this convention (which we may call the negative scale), to use it we must first change the sign of any value in it before applying the last proposition. As that expression tells us that the remainder, on subtracting the former scale value from the actual energy at any point, is constant, this operation of subtraction, after altering the sign of the new scale value, is simply equivalent to adding the new scale value without altering its sign. With this convention, therefore, that an increase of actual energy is a negative increase, or, in other words, a decrease of the negative scale value, we may put the sentence describing the actual energy in every part of the motion in these much simpler words. The sum of the actual energy and of the negative scale value is everywhere constant and equal to the actual energy at the starting-point of the scale, which we may call the initial actual energy. When increase of actual energy coincides with decrease of "negative scale value" (as we have just seen), and also as it is usual to express it with "work done by a force," increase of negative scale value represents work done against a force as it is expressed in the new phraseology of the science of energy, or with "potential work." The actual energy of the material couplet is everywhere fixed and determinate (when it is once started), but if we speak of the negative scale value as "potential energy" the amount of this at various distances depends upon the distance chosen as the initial one, when it is zero. Thus if we reckon the potential energy of a swinging pendulum, drawn by gravitation towards the centre of the earth (whose motions of rotation and of oscillation relatively to the common centre of the globe and of the pendulum-bob may be disregarded, so that, with the exception of gravity, only a force perpendicular to its motion guides the bob in a space, referred to the common centre as origin, which we may identify with the place of the experiment) from the top of the arc, where the actual energy of the bob is zero, this must be the sum of the values of the actual and potential energies throughout the motion, and consequently at the highest point the potential energy is zero, and everywhere else it is negative, while at the lowest point of the arc, where the actual energy is a maximum, the potential energy reaches its greatest negative value. If, on the contrary, we select the lowest point of the arc as the starting-point, and call the potential energy at this point zero, making the sum of the two in all parts of the motion thereby equal to the greatest value which the actual energy can have, the potential energy must elsewhere supply the deficiency as the actual energy abates, or have positive value in all other positions of the bob, and at the highest points of its swing, when the actual energy entirely disappears, it will reach its greatest positive value, equal to the greatest value of the actual energy at its lowest point. By one such system, therefore, the motion is as perfectly described as by the other, and by a different choice of zero-points the individual amount of the potential energy is thus evidently disposable at pleasure, while its difference between two points yet always remains the same. But by taking the zero point where the actual energy has its greatest value, the advantage is obtained, as in the last arrangement for a pendulum, that the potential, like its partner, actual energy, will never be less than nothing, and its values will always be positive. With its zero point so taken, and with a special choice of mass in the moving body attracted or repelled, whose course is followed, the series of negative scale values or of potential energies just described is termed "the potential" or the "potential function" of the force upon it; but its definition for any permanent force-pair supposes the total absence of all such constraining forces as these of the pendulum string, and the bodies must be left perfectly free to approach or recede from each other to the centre, or to the furthest imaginable distance unimpeded by any forces foreign to the pair. In such material couplets it is also sometimes customary to reckon their combined energies actual and potential in a space having for its origin one of the bodies themselves instead of the centre of their mass. The motion of the standard body then disappears, and that of the other body becomes the relative motion of the two, while at the same time a certain mean mass must be supposed centred in the moving body, so that when the product of this, multiplied by its new acceleration, is taken, its impulse relatively to the stationary body (which is now the rate of change of energy of the pair with the distance between them) may not undergo any alteration by the change of origin. Reckoned in this way, either of the bodies may be said to have energies of motion and configuration in the space relative to the other body, whose sum is constant.

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(*To be continued.*)

Aid of the Sun in Relation to Evolution

IT is not often that it will fall to the lot of the physicist to harmonise such important theories as those of evolution and the nebular hypothesis, and much credit is due to the boldness and the originality of Dr. Croll's attempt to do this. At the present time the great majority of scientific men hold the truth of both of these hypotheses in spite of the fact that serious difficulties exist in them which admit of only doubtful explanation, so that it is certain they would be considerably strengthened if it were found possible to dovetail them one to the other without unduly straining the conditions of either. That Dr. Croll has effected this important service is, I think, very questionable, although I fully believe it is attainable.

In advocating his own views in NATURE (vol. xvii. pp. 206, *et seq.*), and in his other publications Dr. Croll has anticipated

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purpose of mechanics). If we continue this process until all the bodies of the material universe are brought, with a knowledge of their masses, under our observation, we reach that abstract field of force, or force-space, which is contemplated in Newton's enunciations. This space may be identified with absolute space, because the centre of mass of the universe by which it is defined is as perfectly abstract and metaphysical an idea as any that we can form of absolute space, on the simple ground that we have no reason to attribute to matter a less boundless and limitless extent in the universe than we ascribe to space itself. To define one metaphysical idea by another is not unscientific, nor is the description of force which Newton gives more repugnant to the eyes of common sense than the ideas which we form, though quite indefinite, of the extent of the material universe, and of the boundless realms of space. A special office, it may also be suggested as very probable, may be assigned to force, to avoid the occurrence of superposition and mingling of matter in the same points of space, or to give matter impenetrability.

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two formidable objections which he foresaw would be brought against them, namely, the improbability of two bodies endowed with enormous energy in the form of rapid motion coming into actual collision with one another, and secondly, the want of experience of like movements in the universe. It is but seldom that a theory, however ingenious, can be upheld against *two* antecedent improbabilities, but granting Dr. Croll all he asks, even to the existence of non-luminous bodies moving through space with a velocity of 1,700 miles per second, there may still be brought more serious objections than either of the above. Our knowledge of the actual motions of the stars in space has recently been greatly extended, and it is now well known that proper motions exceeding thirty miles per second are very rare, and that probably there is no well-authenticated case of a velocity greater than forty miles per second. It has long since been ascertained also that the proper motion of our own sun in space is at the rate of four miles per second only. It is, of course, possible or fortunate that the two bodies from whose collision the solar nebula originally derived its vast stores of heat might be of such equal masses and velocities that the motion of translation should be so nearly destroyed, and the whole converted into heat, but it is inconceivable that amid all the diversity of dimensions of the heavenly bodies it should invariably happen that the resultant movement of the combined masses should be reduced to such insignificant figures as the above.

It is strange that it should not have occurred to Dr. Croll that the heat generated by the impact of two bodies in such rapid motion cannot be considered as remaining constant for nearly the length of time he computes, because the rate of radiation from so intensely heated a sun will be enormously greater than it is now. Indeed the origin of the solar heat does not materially affect the question at issue, which is rather of the means of continuous and equable supply than of the primary source. The contraction theory of Helmholtz addresses itself to meet this difficulty, but alone it is probably insufficient. In the *Popular Science Review* of January, 1875, I have directed attention to other possible and supplementary means of heat supply, which, being continuous, will tend to prolong the period during which the radiation of heat from the sun shall be nearly constant, and hence favourable to the development of organic life. Without advocating any peculiar views of my own which recent discoveries have necessarily somewhat modified, I content myself with pointing out what appear to me to be grave difficulties in the way of accepting the theories and explanations of Dr. Croll.

JOHN I. PLUMMER

Nacton, Ipswich

Faraday's "Experimental Researches"

DOUBTLESS many of your readers will have observed an advertisement of a well-known antiquarian bookseller professing to be able to supply "a perfect copy" of Faraday's "Experimental Researches" at a price not too exorbitant for a complete original copy of that priceless work.

Any who may have applied for the work will, perhaps, share with me the indignation with which they discover that the so-called *perfect copy* is only such in virtue of being a "facsimile reprint" (*sic*) not twelve months old, though dated on the title-page 1839. But perhaps scientific men are too innocent of the ways of antiquarian caterers to receive with calm contentment the assurance that they have not been deceived.

SILVANUS P. THOMPSON

University College, Bristol, February 5

CLAUDE BERNARD

IN rapid succession we are compelled to chronicle the recent serious losses by death to French science. To the names of Leverrier, Becquerel, and Regnault, we regret to add that of the equally famous physiologist, Prof. Claude Bernard, who died in Paris on the evening of February 11. He was born at St. Julien, near Villefranche, in the Rhône department, July 12, 1813. After completing a course of study in the Paris faculty of medicine he was appointed hospital-surgeon in 1839. Two years later he became assistant to the well-known physiologist, Prof. Magendie, in the Collége de France, and continued in close connection with him for thirteen years, during the last half of this time lecturing himself as *privat-docent*. A series of notable discoveries made during this period caused his election, in 1854, to the Academy of Sciences, and his appointment to the newly-founded professorship of general physiology in the Collége de France. This he exchanged in the following year for the chair of experimental physiology, a position which he occupied up to the time of his death.

As an original investigator, Bernard stands among the foremost of the century. He entered upon his career at the epoch when Magendie, the chief founder of the modern French school of physiology, had completely altered the character of this study by the introduction of a variety of experiments on living animals, such as the action of the alkaloids, &c. Bernard entered with enthusiasm on the new field of experimental activity opened up by his master, and by a swift succession of remarkable discoveries with regard to the changes taking place in the human organism, guided the young science into a completely new channel. Of these the most important were connected with the phenomena of digestion, and especially the relation of the nerves to these processes. Perhaps the most valuable was the exhaustive investigation into the functions of the pancreatic juice (in 1850), in which he showed that this fluid was the only one in the digestive apparatus capable of so modifying fatty matter that it can be absorbed by the chyle ducts, and that the digestion of this portion of the nourishment introduced into the system was its sole purpose in the animal economy. Another discovery at this period, which attracted universal attention, was that of the saccharine formation in the liver. Bernard found that not only was sugar a normal constituent of the liver, but that while the blood, on entering into this organ, was completely free from saccharine matter, large amounts of the latter could be detected after it left the liver to pursue its way to the heart. Interesting as this fact was, it was eclipsed by the discovery of the two remarkable connections between this function of the liver and the nervous system.

It was ascertained, first that this normal formation of sugar in the liver could be totally interrupted by severing the pneumo-gastric nerve in the neighbourhood of the heart; and secondly, that by wounding a certain place on the fourth ventricle of the brain, near the origin of the eighth pair of nerves, it was possible to cause such an abnormal formation of sugar that an animal within two hours after such an operation showed all the symptoms of diabetes. In recognition of these brilliant experiments the physiological prizes of the French Academy were bestowed upon Bernard in 1851 and 1853. In a continuation of this line of research in 1859 he made the important discovery that the sugar for the embryo is prepared in the placenta, and not in the liver. Shortly previous to this time he published the results of extensive observations on the temperature of the blood, in which he showed that remarkable alterations in the degree of warmth take place on the passage of the blood from one organ to another, especially in the different parts of the digestive and respiratory systems. The absorption of oxygen by the blood formed the subject of a memoir in 1858, from which it appears that the coefficient of absorption diminishes gradually with an increase of temperature, and becomes zero at 38°—40° C. in the case of mammals, and 40°—44° C. in the case of birds, viz., at the temperatures at which death sets in. The respective amounts of oxygen in the arterial blood, and red and black venous blood were likewise carefully estimated, and the chemical causes for the differences in colour revealed. Among the other leading researches of Bernard must be mentioned those on the comparative properties of the opium alkaloids; on the poisonous properties of curarine; on the sympathetic nerves in general; as well as numerous investigations on the individual processes in the act of digestion. Many of these discoveries, as well as the results deduced from them, have formed subjects for long-continued controversies. With rare exceptions, however, not only

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